Coarticulatory organization in beginner readers: a multifactorial interaction approach

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The present study investigates a possible relationship between children's reading proficiency, phonological awareness and speech production. The link between literacy and phonological awareness, the knowledge of the phonological structure of the language, has been evidenced across languages [German: Fricke et al. 2008, 2016; Landerl & Wimmer 2008; English: Brady, Braze, & Fowler, 2011; Goswami & Bryant, 2016]. However, to our knowledge, very few studies have examined the effects of literacy and/or PA on speech production. Based on a comparison of speech production parameters (accuracy and stability) between typically developing children, adults and dyslexic adults, Saletta and colleagues (2015, 2016) have argued for a link between reading skill and speech movement stability (measured as lip aperture variability). Investigating coarticulatory patterns in first grade German children, Popescu & Noiray 2019 have showed that more proficient readers exhibit less temporal overlap of lingual articulatory gestures between consecutive speech segments in CV syllables, indicating a more differentiated segmental organization. Similarly, Noiray et al 2019 have demonstrated a link between phonological awareness and coarticulatory organization. They argued for a skill-based approach to speech production development as an alternative to the classic age-based approach. A multifactorial analysis, combining phonological and reading skill, has not been proposed yet. This is the goal of the present study: to tests for a three-way interaction between speech production, phonological awareness and reading skill in German children at the early stage of reading instruction. More specifically, we ask the question whether the *combined* effect of phonological awareness (PA) and reading skill correlates with specific patterns of coarticulatory organization. We expect children with lower levels of PA (a group generally associated with lower reading proficiency) to exhibit higher degrees of intrasyllabic coarticulation (ie greater temporal overlap between consecutive consonantal and vocalic lingual gestures). To test this hypothesis, we conducted PA and reading assessments from Fricke & Schäfer (2008) on 34 monolingual German children at the end of the first grade (mean age 7.05, 21 females). The production task consisted in repeating pre-recorded disyllabic target pseudo-words ($\mathbf{C_1V}C_2$ə) embedded in a carrier phrase following the article/aɪnə/. Target vowels corresponded to one of six tense vowels /i/, /y/, /u/, /e/, /o/, /a/while C1/C2 were one of three /b/, /d/, /g/(*e.g. eine bude, eine bade)*. Six repetitions presented in six randomized blocks were elicited. Tongue movement during children's productions was recorded using ultrasound imaging and analyzed within SOLLAR (a Matlab-based platform developed for kinematic data analysis [Noiray et al., first review] to extract coarticulation degree (CD) estimates for each child. Participants were divided into two groups based on their PA level and reading fluency (RF) scores (*accuracy/time)* were calculated for each participant. Even though PA and RF were not highly correlated ($r=0.4$, $p<.001$), with both low and high PA proficiency participants exhibiting similar levels of reading proficiency (up to a certain level), the low PA proficiency group (Fig 1 - in yellow) did not reach high RF scores.

The correlation between children's skill (PA and RF) and CD was analyzed using general additive models [GAMs, Wood 2017] with PA and reading fluency as fixed-factor smooths and participant and consonant (C_1) type as random-factor smooths. Results show a negative correlation between CD and RF *only* for the high PA profi-

ciency group (Fig 2 left): higher scores are associated with lower degrees of intrasyllabic coarticulation. This therefore suggests proficient readers exhibit lower degrees of coarticulation only if they show a high level of PA. This is illustrated by the fanlike structure of the contour lines, which express the positions of the tongue during the midpoint of the consonant as a function of the position of the tongue during the subsequent target vowels (y-axis). For front vowels (e.g. 0.2 value) – in purple – the position of the tongue during the consonant is front for low RF scores (below 0.4) while more central for higher scores (above 0.4). For back vowels (e.g. 0.8 on the y-axis) – in yellow - low RF score participants anticipate the vowel during the production of the consonant (0.7 value on the contour line) while high score participants differentiate the segments more, by exhibiting less vocalic influence on the consonant. In contrast, intrasyllabic CD for the low PA proficiency group is more stable: CD does not differ significantly with increasing RF levels, as illustrated by the parallel structure of the contour lines (Fig. 2 – right).

Fig. 1:PA Proficiency as a function of RF

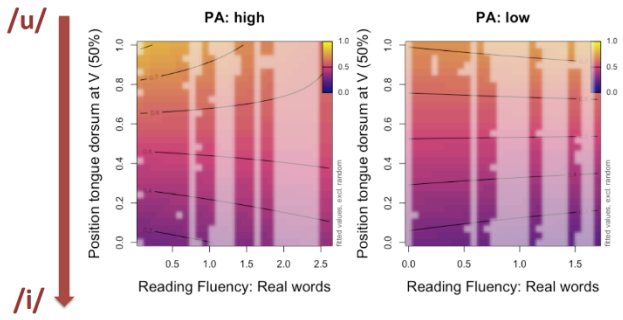

Fig. 2: Contour plots illustrating changes in the tongue dorsum gesture as a function of tongue dorsum position for target vowels (y-axis) and and RF scores (x-axis) for high (left) and low (right) proficiency groups

To summarize, results validate our main prediction that children with better skill levels of phonological awareness and literacy produce greater lingual differentiation for individual segments. More importantly, it seems the findings suggest that a certain level of proficiency in phonological awareness needs to be achieved in order to stimulate greater speech motor differentiation for individual segments. Results further suggest a tight interaction between the development of phonological and phonetic differentiations. These findings point to a dynamic and interactive nature of coarticulatory development.

Selected references:

(1) Fricke, S., & Schäfer, B. (2008). Test für phonologische Bewusstheitsfähigkeiten (TPB). Idstein: Schulz-Kirchner. **(2)** Fricke, S., Szczerbinski, M., Fox-Boyer, A., & Stackhouse, J. (2016). Preschool predictors of early literacy acquisition in German-speaking children. Reading research quarterly, 51(1), 29-53. **(3)** Landerl, K., Wimmer, H., & Moser, E., (1997/2001). Der Salzburger Lese- und Rechtschreibtest. Bern: Hans Huber**. (4)** Noiray, A., Popescu, A., Killmer, H., Rubertus, E., Krüger, S. & Hitermeier, L. (2019). Spoken language development and the challenge of skill integration, Frontiers in Psychology **(5)** Popescu, A., & Noiray, A. 2019. Reading proficiency and phonemic awareness as predictors for coarticulatory gradients in children. Proceeding of BUCLD 44 **(6)** Saletta, M., Goffman, L., & Hogan, T., P., (2016). Orthography and Modality Influence Speech Production in Adults and Children, JSLHR, 59(6):1-15 **(7)** Wood, S., 2017, Generalized Additive Models: An introduction with R. 2nd Edition, Chapman and Hall/CRC